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LARGE SCALE GAP TEST: INTERPRETATION OF RESULTS FOR PROPELLANTS (U)

15 MARCH 1961

U. S. NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND

NAVWEPS Report 7401

LARGE SCALE GAP TEST: INTERPRETATION OF RESULTS FOR PROPELLANTS

Prepared by: DONNA PRICE

Working Group: R. A. Clairmont, Jr.
I. Jaffe
D. Price
G. Roberson

Approved by: Evan C. Noonan, Chief
Physical Chemistry Division

ABSTRACT: This report summarizes recent information and applies it to a more quantitative interpretation of shock sensitivity (gap) test values than previously available. It was found that a GO in this test means that the witness plate is subjected to a shockwave of 95 kbar pressure or more; a NO GO for high energy explosives and propellants most probably occurs because of the physical condition of the test material. Sensitivity ordering by shock amplitude at the end of the gap was found to be the same as that obtained from induced pressures in ten materials for which the comparison could be made. The Appendix compares gap and wedge test results for explosives; the comparison suggests that both are part of a continuous curve showing the shock initiation behavior of the material at varying pressure levels.

CHEMISTRY RESEARCH DEPARTMENT
U. S. NAVAL ORDNANCE LABORATORY
White Oak, Silver Spring, Maryland

The work reported here was carried out under Task NOL-323, Polaris Program on the Sensitivity of Solid Propellants. By use of recently available information the meaning of the shock sensitivity (gap) test values is determined and applied to probable detonability of the test material. The results are considered important for hazard classification and have, therefore, been transmitted to that work group of the Armed Services Explosive Safety Board.

W. D. COLEMAN
Captain, USN
Commander

Albert Lightbody
ALBERT LIGHTBODY
By direction

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Shock sensitivity tests carried out in this Laboratory during the past year have confirmed the solid propellant detonability results that were reported previously (1) and that are briefly summarized at the end of this report. While the general picture remains unchanged, a large amount of supplementary information which allows more quantitative interpretation of the gap test results has been obtained. It is the purpose of this paper to summarize such information and to apply it to various practical situations.

NOL GAP TEST CONFIGURATION

Fig. 1 illustrates the standard assembly for the NOL gap test. Its most important features are: a 5.08 cm length of pressed tetryl (ρ_o = 1.51 g/cc) to supply the shock, Lucite, or the equivalent cellulose acetate, as the shock attenuator, a moderately confined acceptor charge of 3.66 cm diameter x 13.97 cm length, and a mild steel witness plate 0.952 cm thick. The criterion of "detonation" used is the punching of a hole in the witness plate. The measure of charge sensitivity is the length of attenuator (gap length) at which there is 50% probability of detonation according to the above criterion.

CALIBRATION OF THE GAP TEST

Measurement of shock velocity in Lucite under the shock loading provided by two tetryl pellets (Fig. 1) combined with the equation of state data for Lucite and the general relationships of hydrodynamic theory permit calibration of the gap test to obtain shock amplitude (pressure) as a function of distance travelled through the attenuator for the configuration of Fig. 1. Such a calibration has been made (2); its results can be most simply presented for Lucite of density of approximately 1.18 g/cc as follows:

$$U = 2.588 + 1.514\,u \qquad (1)$$

where U is the shock velocity and u is the particle velocity in Lucite; both are expressed in mm/μsec. Equation (1) has been extrapolated for a very short distance, and was used rather than other possible relations because its linearity simplified such extrapolation. From Eq. (1) and the hydrodynamic relationship derived from the conservation of momentum,

$$P = \rho_o U u \qquad (2)$$

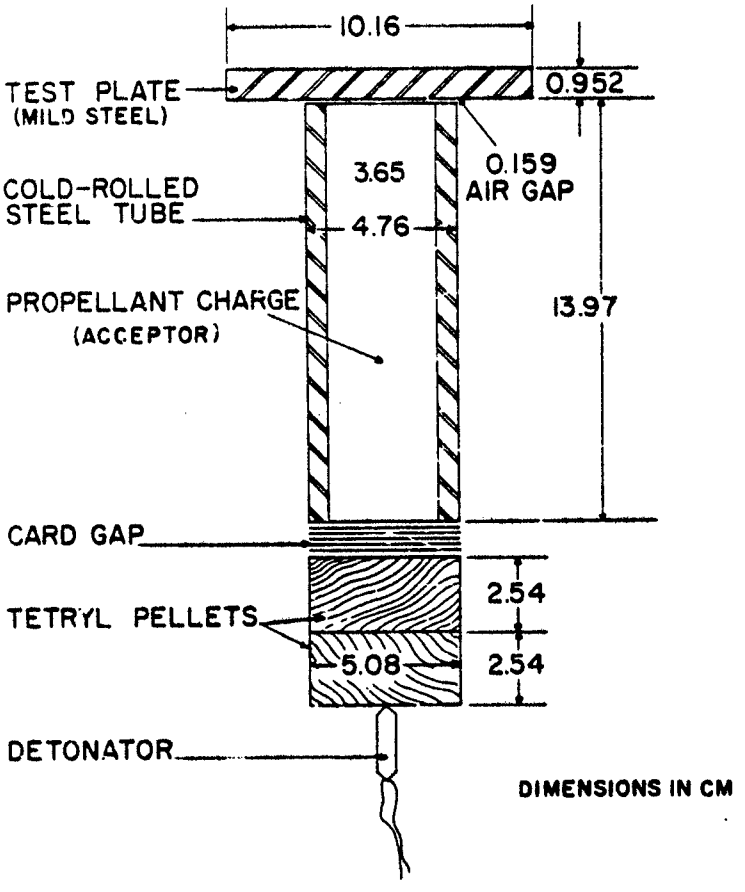

FIG. 1 CHARGE ASSEMBLY AND DIMENSIONS FOR NOL GAP TEST

where P is pressure (kbar x 10^{-1}) and ρ_o (g/cc) is the initial density, it is possible to obtain the non-linear pressure-particle velocity curve for Lucite. This curve is generally called the Hugoniot adiabat or the equation of state. The more familiar pressure-compressibility curve

$$P = P(\rho_o/\rho)$$

can be obtained by combining Eqns. (1) and (2) with

$$\frac{u}{U} = 1 - \frac{\rho_o}{\rho} \qquad (3)$$

It is much more customary as well as more convenient to work with a P - u curve than with a P - ρ curve because boundary conditions for reflection and transmission of shockwaves at the interface between two different materials require that pressure P and particle velocity u must be equal on each side of the boundary. The convenience will be illustrated in an application in a later section.

Eqns. (2) and (3) are applicable to any material under shock conditions, and Eq. (1) is the general equation for shocked Lucite. The relationship between shock pressure and distance of travel, restricted to Lucite in this experiment is

$$P = 105\ e^{-0.0358x} \qquad x \geq 20 \text{ mm.} \qquad (4)$$

where x is the thickness of Lucite through which the shock has travelled. Eq. (4) is an approximation good to about 5% in pressure. For more accurate values and for gap thicknesses less than 20 mm, the tabulation or graph of Reference (1) must be used.

USE OF SHOCK AMPLITUDE TO DEFINE SHOCK

The effects of shocking a material are undoubtedly caused by the pressure loading of the material i.e., to the shape of the pressure-time profile of the shockwave. In the absence of quantitative information about the nature of this profile and for simplicity of presentation, the discussion below will be presented as if the amplitude alone fully defined the shock. This is equivalent to assuming that in the systems considered (a condensed medium such as Lucite or brass shocked by detonation of an organic explosive such as tetryl or Comp B), the impulse is a uniformly varying function of the amplitude. There is some slight experimental evidence that this may be the case for decaying shocks. See Appendix.

Study of shockwave pressure-time profiles and their effects on shock sensitivity are now being carried out at NOL and other laboratories. Results will not be available for some time. Meanwhile, the simplification of describing the shockwave by its maximum pressure has been adopted, but it will be reexamined as more information becomes available.

MEANING OF A "GO" ACCORDING TO TEST CRITERION

The criterion for a GO in the gap test of Fig. 1 is punching a hole through the witness plate. It was found that the tetryl loading attenuated by 100 cellulose acetate cards (equivalent to a 2.54 cm thickness of Lucite) resulted in a 50% probability of punching such a hole. This gap thickness corresponds to a pressure of 43 kbar at the end of the gap. To determine the pressure transmitted into the plate, the Hugoniots of iron (3) and of Lucite [Eqns. (1) and (2)] are used. Fig. 2 illustrates the customary method (3). When the shock reaches the interface, Lucite - iron, its P - u values are 43 kbar and 0.91 mm/μsec respectively or point (a) of Fig. 1. At the interface a reflected shock (dashed line) is sent back into the Lucite; this raises the pressure and particle velocity to the values at point (b) which are also the values for the shock transmitted into the iron. The necessary pressure to punch the hole in the witness plate is thus found to be 95 kbar. Hence a GO, by this criterion, means that the explosive reaction has been sufficiently vigorous to develop a shockwave pressure of 95 kbar or greater strength in the witness plate. In contrast to the inert Lucite, a reacting material may load the plate not only by shock but also by high pressure gas reaction products; this is discussed later.

It should be noted that a GO does not necessarily signify high order detonation which is the steady-state maximum rate for the given material in the geometry of Fig. 1. It has been found (4) by the wedge technique that cast TNT (ρ_o = 1.58) exhibited a constant velocity of 5.23 mm/μsec instead of the expected 6.7 - 6.8. A similar low velocity at the 50% point has been observed by the continuous wire method (5). It follows that TNT explodes with sufficient violence to puncture the plate without detonating. By applying the usual boundary approximation (2) between cast TNT and iron and using the limit of 95 kbars as necessary for puncture, it is evident

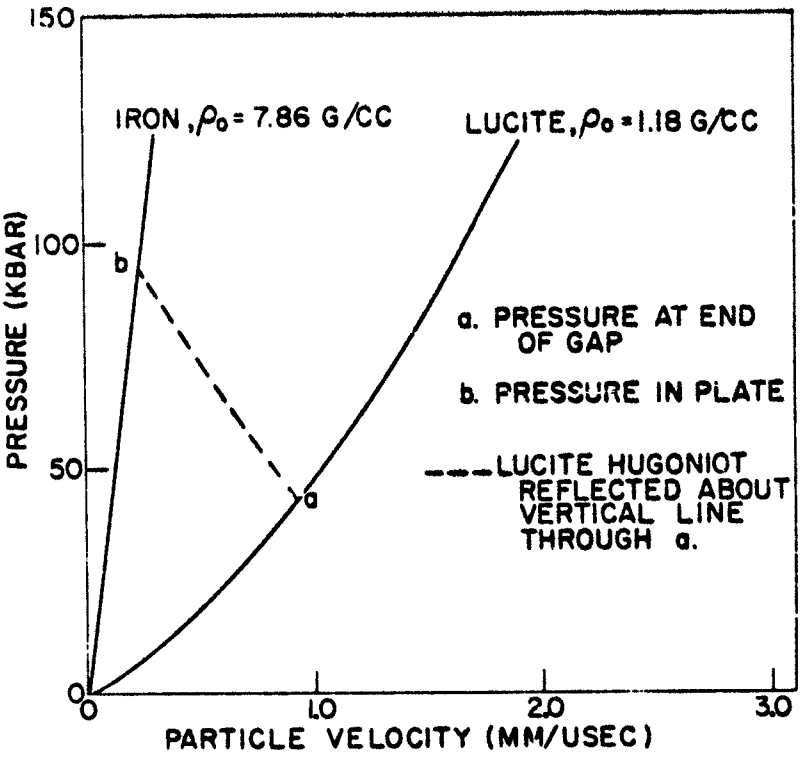

FIG.2 DETERMINATION OF SHOCK PRESSURE IN WITNESS PLATE

that the TNT reaction develops at least 58 kbars pressure.* Since the separation between the end of the acceptor and the witness plate (0.159 cm) was neglected in this calculation, the estimate of 58 kbars is a lower limit; the actual pressure required for plate puncture would be somewhat higher.

On the other hand, it is possible for a borderline material such as ammonium perchlorate (AP) to exhibit its steady-state maximum rate and still not produce a plate puncture. For example, AP of an average particle size of 25 μ and a loading density of 1.23 g/cc exhibited a NO GO. It is possible that 5.56 cm is just below the critical diameter (7) for this sample, but for this illustration it is assumed that the maximum rate, 4.32 mm/μsec (7), was achieved. Again, by the boundary approximation (not a very good one in this case since the AP is highly compressible), the unpunctured plate indicates that less than 54.2 kbars (again, a lower limit) pressure was developed in the AP. The computed detonation pressure (7) for this AP is 54.4 kbar. At lower loading densities, the situation is even more clear-cut.

While various charges of AP tested in the geometry of Fig. 1 did not puncture the plate, they did make it bulge. In fact, the hump formed increased in size as the loading density of the charge decreased; the largest hump or bulge was of about the same size as that obtained without a charge present i.e., with only air in the acceptor tube. Early in the development of the gap test, formation of a bulge in the witness plate was used as a criterion of a GO. It was soon replaced by the present criterion which is a far more satisfactory one. The behavior of an air acceptor, however, casts some light on the inadequacy of bulge formation as a criterion.

The witness plate bulge obtained with an air-filled tube and zero gap is caused by the loading produced by the gaseous detonation products of tetryl, not by the air shock. This is easy to show by firing with water in the tube instead of air; in this case the plate is undamaged. The shocks produced by

*It is of interest that the rate of 5.23 cm/μsec is that expected for TNT at a loading density of 1.02 g/cc. The measured detonation pressure at $\rho_o = 1.00$ is 64 kbar (6).

the detonation of tetryl in air and in water are about 0.5 kbar and 16.5 kbar, respectively. With no attenuation, these would create less than 4, (8* x 0.5), and 38 kbar, respectively, in the plate. Consequently any shockwave damage would be greater from the water than from the air. It follows that loading the plate by the detonation products, which are stopped by water or any other inert condensed medium, causes the plate bulge (the same factor incidentally must be responsible for initiation across an air-gap). In the case of very low density, porous acceptors, zero gap tests that produce a bulge may do so because of the action of the tetryl products on the plate, because of a decomposition of the charge to produce high pressure products, or because of a combination of these two factors. The bulge is, therefore, very difficult to interpret quantitatively.

APPROXIMATION OF PRESSURE IN CHARGE BY PRESSURE IN LUCITE

Determining the shock pressure in the acceptor charge from the shock pressure in the Lucite at the end of the gap is a problem identical in principle to that solved in Fig. 2. The significant practical difference is that the P-u curves for cast or extruded charges lie close to the P-u curve for Lucite, though still above it. It is to be expected, therefore, that the initiating shock pressure will be somewhat larger than the pressure at the end of the 50% gap.

A quantitative determination of the initiating pressure requires either equation of state data or shock velocity data of the solid charge material. In general, these data are not available, and the shock pressure at the end of the Lucite gap is used to give a rating that is assumed to be a good approximation to that which would be given by the true initiating pressures.

Recently, equation of state data for unreacted TNT have been published (8)**. These together with pressures induced

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* The maximum reflection coefficient of 8 is for air with a heat capacity ratio of 1.4.

** In this reference, there was a discrepancy between the tabulated U-u data and the analytical expression relating them. For the present work, the tabulated data were used; they were found to fit the relation

$$U = 3.045 + 1.3193\ u$$

in different explosives by the same shock loading (9)* permit a test of the assumption. Fig. 3 shows a comparison of the pressure at the end of the Lucite gap with the pressure in the charge for six cast and three pressed high explosives. See Appendix. There is no reversal in the sensitivity ordering although the initiating pressures are 16-30% higher than the corresponding Lucite pressures. The assumption that the latter will give a correct sensitivity ordering for dense charges seems justified.

MEANING OF "NO GO" ACCORDING TO TEST CRITERION

High energy propellants and explosives would be expected to detonate under appropriate conditions. Failure or NO GO for the test configuration of Fig. 1 might result from one of three possibilities:

1. The material, in the form tested, is detonable but its critical diameter for detonation is greater than 3.66 cm in the confinement of Fig. 1.

2. The material, in the form tested, is detonable but it requires stronger boostering than that effected by the tetryl of the standardized test.

3. The material, in the form tested, is not detonable, i.e. a critical diameter does not exist for that physical form.

The critical diameter is that diameter below which detonation cannot be propagated. Obviously, this diameter must be exceeded before a GO can be obtained. The test diameter of 3.66 cm and moderate confinement, which makes the effective diameter somewhat greater than 3.66 cm, is a very generous allowance on this score. Recent measurements of critical diameter for nine cast explosives gave values of 0.4 - 2.69 cm (10). Of the four pressed explosives studied, the maximum critical diameter was 1.3 cm (11). Even ammonium perchlorate, not of itself a high energy material, exhibits a critical diameter of only 1.63 cm when particle size and density are sufficiently low (7). It is, therefore, very unlikely that this factor is responsible for a NO GO.

* Revision of Reference (4) data was made by use of recently measured, more accurate surface velocities (15).

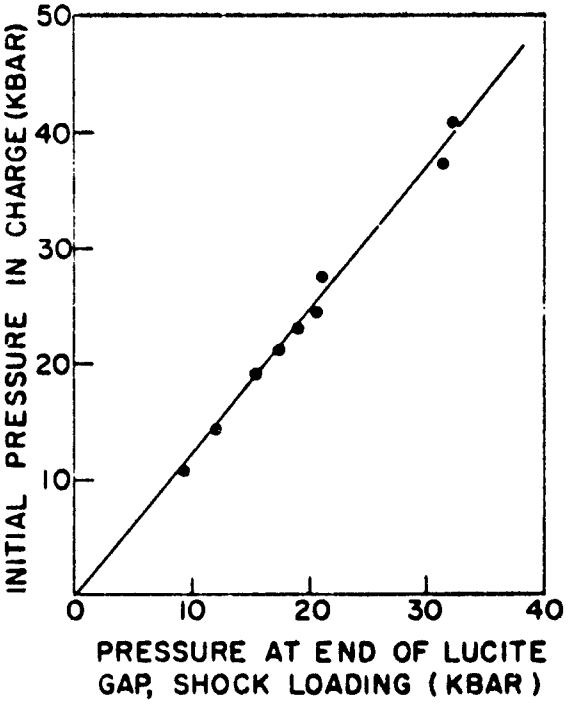

FIG.3 COMPARISON OF SHOCK LOADING AT 50% POINT WITH INITIAL PRESSURE IN CHARGE

While it is conceivable that the tetryl would be too weak a booster for some materials, in the several cases that tetryl was replaced with a more powerful booster the result was still a NO GO. This, too, is regarded as an unlikely cause for the charge failure.

By far the most likely cause of a NO GO for a high energy propellant or explosive in this standard test is that the physical form of the test material makes shock initiation very difficult or impossible. The major influence of physical properties is well known. For example, pressed TNT can be detonated by an initiating shock of 23 kbar, cast TNT explodes with an initiating pressure of 37 kbar, and liquid TNT can support shocks as strong as 110 kbar without showing evidence of chemical decomposition (12). Pressed nitroguanidine (25% voids) has a gap test value of 3.56 cm; pressed nitroguandine (4.5% voids) cannot be detonated in a 5.08 cm diameter with 1.27 cm thick wall confinement and with a booster of 50% greater detonation pressure than that of tetryl (13). Finally, composite propellants (AP/organic binder* or AP/organic binder/Al) will not detonate in the form produced by the manufacturers but will exhibit a GO after about 10% connected voids have been introduced into the material (1).

On the basis of such information and of the discussion above, it is concluded that a NO GO in the standard test is a very strong indication that the material is not detonable in the physical form and at the temperature used for testing. High probability of non-detonability does not mean that the detonation of nitroguanidine (4.5% voids) or of composite propellant (manufacturer's density) is impossible. It does mean that a higher initiating shock strength than 86 kbar or a larger effective diameter than that of Fig. 1 or both will be required to detonate these materials if they are detonable at all.

In addition to the guidance offered by the GO - NO GO testing described above, additional information useful in selecting propellants for various applications is provided by Macek's studies of the transition from burning to detonation (14). He found that the burnt gas products must produce a pressure of such a rapidly increasing rate as to form a shock; the shock then initiates the unburned material. Initiation by shock, as in the GO - NO GO testing, is a limiting case of transition from burning to detonation. Macek found that a

* Non-explosive

rapidly accelerating pressure rise to 32 kbar was necessary to effect transition to detonation in his experimental configuration with two relatively shock sensitive high explosives. It is questionable that the much less sensitive propellants can burn in such a manner as to produce the very high time rate of change of pressure of the gas products or the maximum boundary pressure required for detonation provided they are examined in the small diameter and high confinement of Macek's experiment. The burning of large grain propellants is a very different matter in that there is a large possibility of a change of the physical state, e.g. thermal or mechanical fracture to expose new surfaces for reaction. If this should occur, the shattered propellant may well be detonable (see results for porous propellant below). No large scale test of detonability can give any information about the probability of such a physical change in the propellant during burning; other testing procedures must be devised to obtain that information.

SUMMARY OF PROPELLANT SHOCK SENSITIVITY BEHAVIOR

All of the test results obtained at NOL by testing propellants in the configuration of Fig. 1 can be summarized in the table below.

SHOCK SENSITIVITIES AT 25°C

Propellant	Physical State	Loading pressure at 50% point, kbar
Composites	As received, non-porous	NO GO
Double-Base	As received, non-porous	80-47
Composite Plus 17-18% H.E.	As received, non-porous	69-58
Composite	Shredded and pressed; 16-22% connected pores	11-7

CONCLUSIONS

The chief conclusions which can be drawn about the NOL shock sensitivity test in view of our present information are:

1. A GO means that a shockwave of 95 kbar or greater was transmitted to the witness plate; it does not necessarily mean high order detonation of the test charge.

2. A NO GO for high energy propellants and explosives is probably caused by the physical state (particle size, porosity and temperature) of the test material.

3. Sensitivity rating by shock amplitude at the end of the gap gives the same ordering as that by shock amplitude in the charge for the ten explosives for which Hugoniot data are available.

ACKNOWLEDGMENT

The writer acknowledges, with gratitude, several very helpful suggestions from Dr. S. J. Jacobs.

APPENDIX

COMPARISON OF WEDGE TESTS RESULTS WITH GAP TEST VALUES

The shock initiation of heterogeneous high explosives was studied by means of the wedge technique several years ago (4). The booster used in that work was a combination of a plane wave booster followed by cyclotol 60/40 giving an effective booster thickness of about one inch; the attenuation was by three thicknesses of brass plate. Subsequent to the original work, it was found that the charge geometry used did not produce a uniform particle velocity. As a consequence, the experimentally observed particle velocities were in error. New measurements showed the original surface velocities observed to be some 20% higher than the correct values (15). Consequently the shock pressures originally reported are too high.

By use of the corrected surface velocities (15), J. F. Wehner obtained revised pressure data. He used LASL equation of state data for brass (3). (The brass used at LASL and Navy brass differ somewhat.) From the Hugoniot and the measured surface velocity of brass as a function of brass thickness, the pressure at the end of the attenuator can be found. Then the intersection of the brass P-u curve, reflected at the pressure at the end of the brass gap, with the line from the origin of slope $(\rho U)_{explosive}$ (4) is the pressure of the shock entering the explosive.

Jacobs (4) examined the variation of delay time τ as a function of induced shock pressure; the delay time is defined as

τ = (time to steady detonation) - (time if steady velocity existed throughout).

$$\tau = \tau_s - \frac{x_s}{D} \qquad (1)$$

where τ_s = time to steady detonation

x_s = length of run to steady detonation

D = velocity of steady detonation

The delay time has the nature of an induction time, but its determination as the difference of two quantities of the same order of magnitude subjects it to an intrinsically large

experimental error. For this reason, the data for the six cast explosives were also examined for the variation in total time to steady state and length of the run to steady state as a function of the shock pressure. Because of the form of the P vs τ curves of Ref. (4), curves of the reciprocals of τ, τ_s, and X_s vs P were examined. The necessary data are given in Table A-1. In each case (τ^{-1} vs P, τ_s^{-1} vs P, and X_s^{-1} vs P), the three points are approximately linear and, in each case that high order detonation was achieved, the sensitivity ordering for these particular charges is the same. For increasing sensitivity, this order is cast TNT*, cyclotol 75/25, Comp B, pentolite, octol 65/35, and cyclotol 60/40.

The relation between length of run and shock pressure was used in examining additional data both because X_s might be measured more easily than τ and because the gap test data might provide a fourth point on the curve. In order to use gap test data, it is necessary to know not only the shock pressure at the end of the Lucite gap but also the induced shock pressure in the high explosive. The latter data were obtained, as explained in the text, by using the Hugoniot for Lucite and that for "fused" TNT (8) to get the pressure that would be transmitted through each gap into cast TNT. This value was then multiplied by a correction factor obtained by plotting the ratios $P_{expl.}/P_{TNT}$ from table A-1 and Ref. (4) as a function of P_{TNT}; the correction factor varies with the strength of the shock. Table A-2 gives the values of the initiating shock pressures for a number of materials each at its 50% point. Almost any length of run value at the 50% point, minimal initiation, will be large compared to the X_s values of Table A-1. The choice ranges from a radius into the charge (18 mm.) a run for which no attenuation by lateral rarefaction would be expected, to the 46-60 mm. measured by the continuous wire method in confined pentolite (5). As will be seen in the figures, the exact value is not critical; 50 mm. was used for the plots.

Figure A-1 shows the data for the cast explosives which achieved high order detonation. It seems that the shock sensitivity test values are related to the wedge test measurements in that they give the shock pressure required for initiation after a relatively very long run of the shock through the charge. Some of the curve crossing of Figure A-1

* TNT did not achieve high order detonation and was not in this position in ordering by τ^{-1} vs P.

may be due to poor data, to poor selection of curves to fit sparse data, or to the fact that different charges, prepared at different times, were used for the two tests. There is, however, no obvious reason why the curves should not cross i.e., why two explosive materials should not indicate different relative sensitivity at different levels of shock strength. Crossing might also be caused by a duration effect which has been completely omitted in the present treatment.

The most dubious choice of curve is that for Comp B; it was made both because of the location of the terminal point and to obtain conformity with the trends shown by the closely related materials, pentolite and cyclotol 75/25.

The spread of the curves of Fig. A-1 indicates that these data are fantastically sensitive to physical factors which vary with charge preparation. The chemical change of 1% wax is certainly not responsible for the large difference between cyclotol 60/40 and Comp B. Nor is there any chemical reason for cyclotol 75/25 to be less sensitive than Comp B and cyclotol 60/40 or for octol 65/35 to be less sensitive than cyclotol 60/40 - quite the reverse. It seems likely that an attempt to duplicate results without better control of charge preparation would fail.

Comparable initiation data for pressed charges have been collected from several sources in Table A-3. Most of the corresponding curves are shown in Fig. A-2 as well as the curve for cast TNT which did not achieve high order detonation. The latter is shown here rather than in Fig. A-1 because it is thought to be most comparable to DATB. Ref. (16) compared DATB to cast Comp B, but the curve of the latter (Fig. A-1) does not indicate as much resemblance to DATB as does the TNT curve.

For both DATB and DATB/BRL 2741 (DATB/phenolic resin, 95/5) the point at about 83 kbars has been omitted. In the former case this is because the drop-off after the overshoot (16) was so gradual that X_s was uncertain; in the latter, a failure occurred. DATB/EPON 1001 (DATB/epoxy resin, 95/5), however, did detonate at this level, and it would not be expected to differ much from the DATB/BRL. Moreover, a 50% point for initiation at 46 kbar was obtained for the DATB/BRL. For these reasons, the curve has been drawn between the two terminal points.

The data for pressed Comp B indicate the large scatter for a pressed sensitive charge; this is further illustrated by the LASL data for cyclotol 65/35 (17) shown in Fig. A-3. The large difference in sensitivity between this cyclotol and pressed Comp B (cyclotol 60/40 plus 1% wax) may be due to the higher density of the former (1.71 as compared to 1.54), the difference in the shock loadings used, or to both of these factors. There is no terminal (50% point) datum for this material; it is of interest that a straight line for the five points extrapolates to a 50% value in the range covered by pressed and cast Comp B.

The curves of Figs. A-1 to A-3 have been displayed to illustrate three points: (1) the probability that the 50% point gives the limiting pressure for initiation; (2) the large effect of physical properties of the charge on such sensitivity curves and (3) the relative sensitivity of these particular charges. Much more data are needed to establish the true nature of the curves e.g., whether they are linear. Not surprisingly, the curves drawn cannot be extrapolated to higher pressures. For an X_s equal to the reaction zone length of cast and pressed TNT and of cast and pressed cyclotol 63/37 (18), the shock pressure indicated by the linear curves is much greater than a reasonable value of the von Neumann spike pressure for these materials. It is of some interest that many of the sets of data also indicate linearity on a log X_s vs log P plot, and that in several cases these extrapolate to reasonable values at X_s = reaction zone length. The log-log plot was not used in the qualitative discussion because it crowds together the three high pressure points and is too sensitive to the exact location of the terminal (50% point) values.

It is hoped that future investigations will define the role of the impulse in initiation and its relation to the shock amplitude in various boostering systems. Additional work also needs to be done on determining whether the acceptor diameter (Fig. 1) is sufficiently large to give the minimum initiating pressure for an infinite diameter charge.

REFERENCES

1. A. E. Amster, E. C. Noonan, and G. J. Bryan, ARS Journal 30, 960-3 (1960).

2. I. Jaffe, R. L. Beauregard, A. B. Amster, NavOrd 6876 (1960).

3. M. H. Rice, R. G. McQueen and J. M. Walsh, "Compression of Solids by Strong Shock Waves", Solid State Physics, Vol. 6, pp 1-63, Academic Press Inc., New York (1958).

4. J. M. Majowicz and S. J. Jacobs, Tenth Annual Meeting of Division of Fluid Dynamics of American Physical Society, Nov. 1957 (Also NavOrd 5710 (1958), Confidential).

5. I. Jaffe, unpublished work.

6. A. N. Dremin and P. F. Pokhil, Proc. Acad. Sci. (USSR) Phys. Chem. Sect. 128, 839-41 (1959).

7. W. H. Andersen and R. E. Pesante, "Reaction Rate and Characteristics of Ammonium Perchlorate in Detonation", Eighth International Combustion Symposium (1960).

8. V. S. Ilyukhin, P. F. Pokhil, O. K. Rozanov, and N. S. Shvedova, Soviet Physics Doklady 5, 337-340 (1960).

9. Ref. 4, data revised.

10. I. Jaffe, NavWeps 7360, in press.

11. Progress Rept., Project LACE at NOL for July - August 1960.

12. W. B. Garn, J. Chem. Phys. 30, 819-822 (1959).

13. H. Heller, O. H. Johnson, and J. M. Rosen, NavOrd 6038 (1959). Confidential.

14. A. Macek, J. Chem. Phys. 31, 162-167 (1959).

15. Progress Rept., Project LACE at NOL for the Month of August 1959. Confidential.

16. N. L. Coleburn, B. E. Drimmer, and T. P. Liddiard Jr., NavOrd 6750 (1960). Confidential.

17. A. W. Campbell, W. C. Davis, J. B. Ramsay, and J. R. Travis, Shock Initiation of Explosives, Third ONR Symposium on Detonation, Sept. 1960.

18. L. N. Stesik and L. N. Adimova, Russian J. Phys. Chem. 33, 148-151 (1959).

TABLE A-1

SHOCK INITIATION DATA FOR CAST EXPLOSIVES

H.E. Material		Initial Pressure* in H.E., kbar	Delay Time τ μsec	Total Time to Steady State τ_s μsec	Length of Run To Steady State x_s mm.	Reciprocals τ^{-1}	τ_s^{-1}	x_s^{-1}
Pentolite 50/50	1.676	98	0.144	0.546	3.03	6.94	1.83	0.330
		79	0.206	0.691	3.64	4.85	1.45	0.275
		68	0.314	0.885	4.31	3.18	1.13	0.232
Comp B	1.710	97	0.145	0.507	2.86	6.90	1.97	0.350
		77	0.264	0.815	4.38	3.79	1.23	0.228
		67	0.428	1.188	6.03	2.34	0.84	0.166
Cyclotol 60/40	1.723	98	0.091	0.306	1.72	11.0	3.27	0.581
		78	0.137	0.411	2.19	7.30	2.43	0.457
		68	0.206	0.538	2.66	4.85	1.86	0.376
Octol 65/35	1.787	105	0.091	0.328	1.94	11.0	3.05	0.515
		83	0.159	0.479	2.62	6.29	2.09	0.382
		72	0.234	0.653	3.42	4.27	1.53	0.292
Cyclotol 75/25	1.729	100	0.18	0.620	3.62	5.56	1.61	0.276
		81	0.28	0.835	4.56	3.57	1.20	0.219
		72	0.46	1.200	6.08	2.17	0.83	0.164
TNT (cream cast)	1.582	88	0.084	0.894	4.3	13.3	1.12	0.222
		72	0.187	1.287	5.6	4.67	0.78	0.179
		64	0.274	1.944	8.7	3.65	0.51	0.115

* Computed by J. F. Wehner, see text. Remaining data from curves and tables of Ref. (4).

TABLE A-2

INDUCED SHOCK PRESSURES AT THE 50% POINT

Cast Explosives	No. cards at 50% Point	Shock Pressures, kbar At end of Gap	In cast TNT	Correction Factor	Induced Pressure in H.E. kbar
Pentolite 50/50	266	9.3	11.3	0.954	10.8
Comp B	201	17.5	21.5	0.975	21.0
Cyclotol 60/40	184	20.6	25.0	0.98	24.5
Octol 65/35	214	15.3	19.0	1.00	19.0
Cyclotol 75/25	182	21.0	25.3	1.08	27.3
TNT	158	31.3	37.3	1.00	37.3
Pressed Explosives	**Loading Density ρ_o g/cc**				
Comp B	1.66	238	12.0	14.7	0.97	14.3
TNT	1.57	193	19.0	23.0	1.00	23.0
DATB	1.71	135	32.2	39.2	1.04*	40.8
DATB/BRL 2741, 95/5	1.77	120	36.2	44.0	1.04*	45.7

* Obtained from data of Ref. (16).

TABLE A-3

SHOCK INITIATION DATA FOR PRESSED EXPLOSIVES

H.E. Material	ρ_0	Initial Pressure in H.E. kbar	Length of Run to Steady State X_s, mm.	X_s^{-1}
Comp B*	1.545	90	2.0	0.50
		72	1.3	0.77
		64	2.2	0.46
TNT*	1.505	89	2.8	0.36
		80	3.4	0.29
		64	5.0	0.20
DATB †	1.81	99.2	3.3	0.30
		84.1	?	-
		76.6	5.4	0.18
DATB/BRL 2741† 95/5	1.77	99.4	4.8	0.21
		82.0	Failed	-
DATB/EPON 1001† 95/5	1.73	86.0	Detonated, poor record	
Cyclotol 65/35 △	1.71	87.7	5.7	0.056
		56.9	8.6	0.084
		51.2	11.3	0.088
		37.2	11.9	0.12
		35.4	18.0	0.18

* Revised pressures computed by J. F. Wehner, see text. Data from Ref. (4).
† Data from Ref. (16). △ Data from Ref. (17).

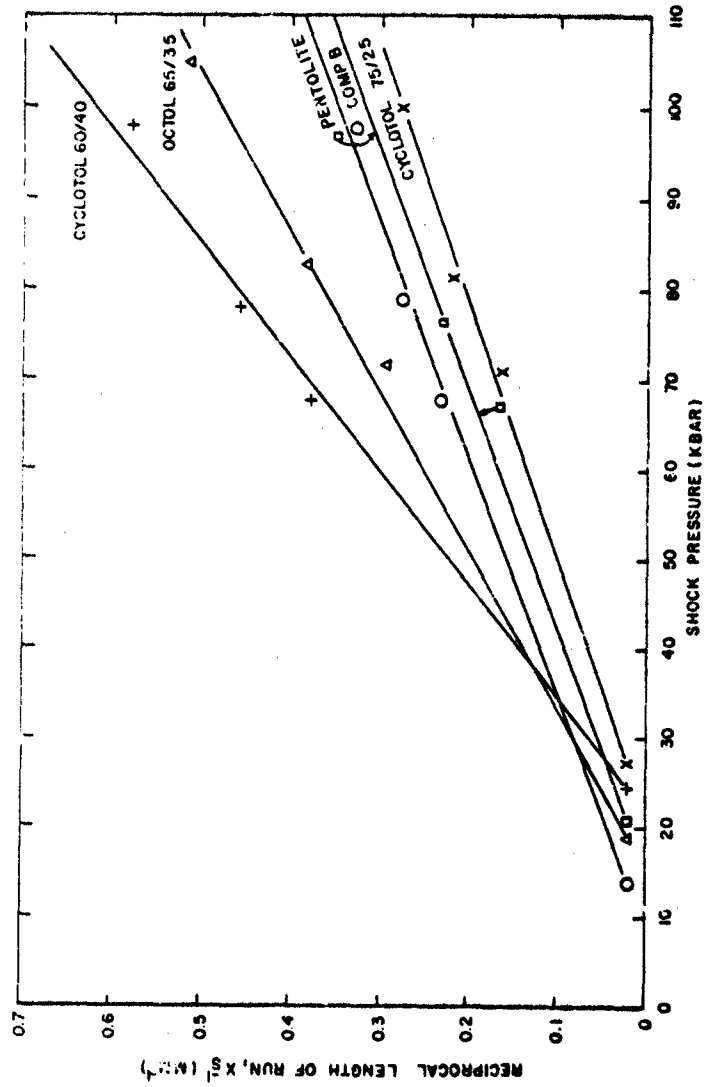

FIG. A-1 SHOCK INITIATION BEHAVIOR OF CAST EXPLOSIVES

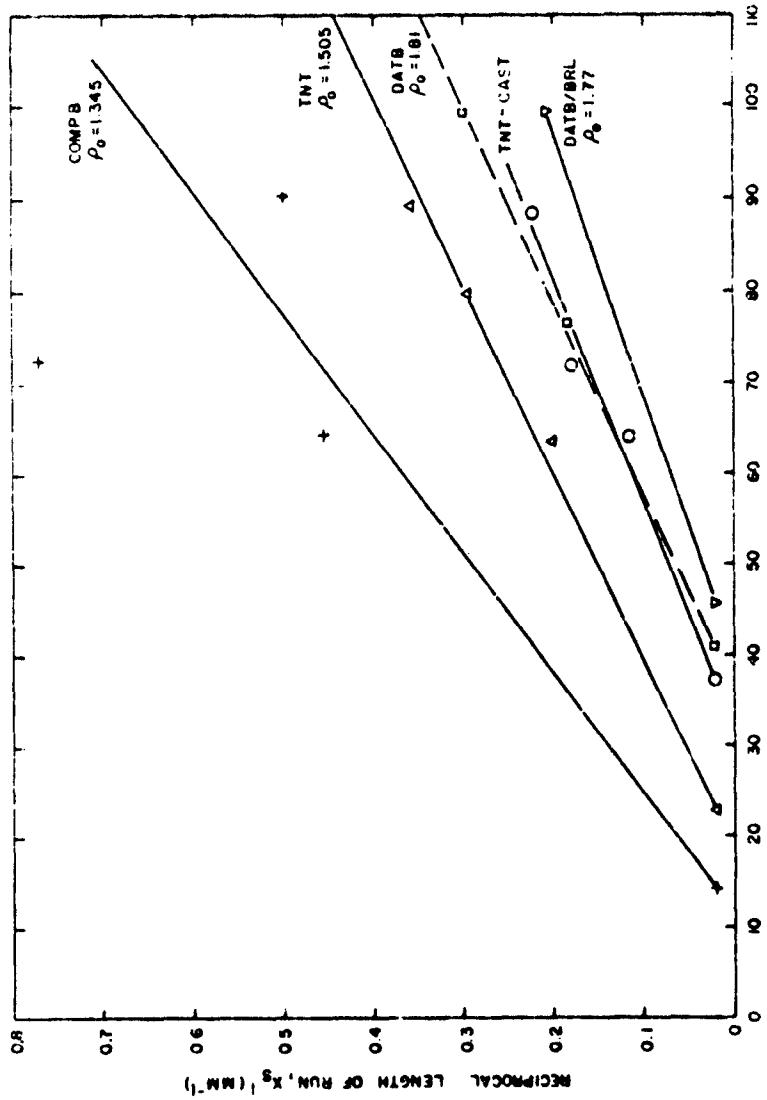

FIG A-2 SHOCK INITIATION BEHAVIOR OF PRESSED EXPLOSIVES

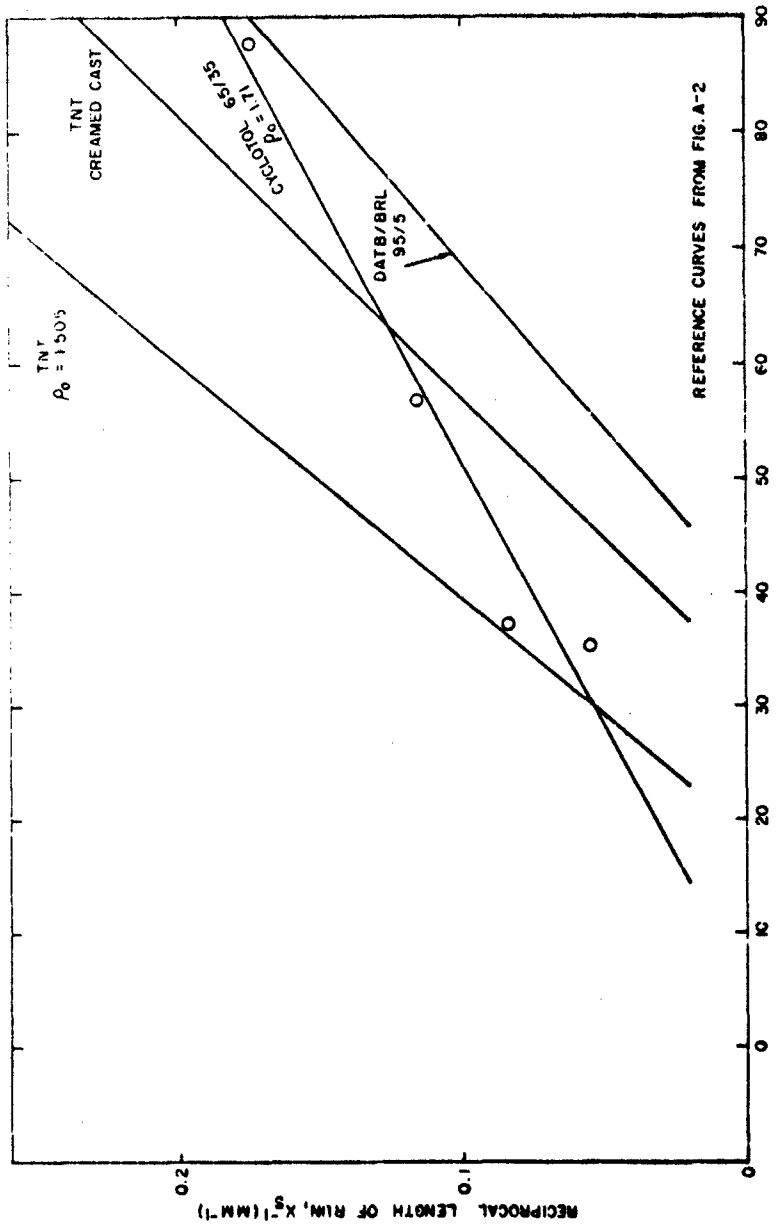

FIG. A-3 SHOCK INITIATION BEHAVIOR OF HIGHLY COMPRESSED CYCLOTOL 65/35

Naval Ordnance Laboratory, White Oak, Md.
(NAVWEPS report 7401)
LARGE SCALE GAP TEST: INTERPRETATION OF RESULTS FOR PROPELLANTS (U), by Donna Price. 15 March 1961. 21p. charts, tables, diagrs. Project [illegible]. UNCLASSIFIED

This report summarizes recent information and applies it to a more quantitative interpretation of shock sensitivity (gap) test values than previously available. It was found that a GO in this test means that the witness plate is subjected to a shockwave of 35 kbar pressure or more; a NO GO for high energy explosives and propellants most probably occurs because of the physical condition of the test material. Sensitivity ordering by shock amplitude at the end of the gap was found to be the same as that obtained from induced pressures in ten materials for which

Abstract card is unclassified (over)

1. Gap tests
2. Propellants - Sensitivity
3. Explosives, Sensitivity
I. Title
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